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FACTORS INFLUENCING STREAM TEMPERATURES

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FACTORS INFLUENCING STREAM TEMPERATURES

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The work on Aim 3 of the research project "Factors Influencing Stream Temperatures" was conducted by John Seaders, Assoc. Prof. of Civil Engineering, Principal Investigator of this project.

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TURBIDITY EFFECTS ON ENERGY GAINS IN WATER

INTRODUCTION

The problem of stream heating from natural insolation has received increasing attention during the last decade. The Water Quality Act of 1965 has propelled the problem of stream temperatures to new prominence for the standards to be maintained are intimately related to the temperature of the stream receiving waste waters. Since all chemical and biochemical reactions are affected by temperature an accurate knowledge of the temperature of a stream is of paramount importance in forecasting and evaluating water quality parameters at specific points in a stream system.

The major natural factors affecting stream temperatures such as solar insulation, longwave radiation, evaporation and conduction are well known. Although it may be safely said that the evaluation of stream evaporation is a nebulous problem not in the principles underlying the process but in its quantitative evaluation. The following aspects of stream or water heating have received little or no attention.

One aspect is the effect of turbidity on the stream or water mass heating rates and another is the effect of different types of bottom materials on the rate of energy absorption. In heat transfer text the different responses of materials are tabulated for application in mechanical heat transfer devices. In nature the material varies both in size and often in color due to chemical variability of the parent rock. Thus different size particles may cause differ-

ences in heat storage in bottom beds especially in streams where the water is very shallow and the stream is wide.

PURPOSE AND SCOPE

The purpose of turbidity and bed material studies as related to radiant heat transfer lies in the fact that, in 1960 when some of the earliest stream temperature studies were conducted, questions pertaining to such factors as turbidity, etc. had to be ignored for lack of factual information. A study of this type was initiated to establish the necessity of incorporating turbidity in future studies which may be expected to be more refined than the initial efforts.

The problem of turbidity was studied by the analysis of a series of basins in which water of various degrees of turbidity were introduced. The temperature values in these basins were observed for 5 days under similar weather conditions, each degree of turbidity having 2 basins to insure that there was not only a check of repeatability during the test period but that daily values were dependable as shown by duplication of the daily results. The second aspect, that of different bottom materials was studied using the same basins, duplicating daily results by use of two basins for each condition and repeating the series for 5 days during which the temperatures in the water mass were observed at regular intervals.

TEST MODEL AND EXPERIMENTAL PROCEDURE

The basic equipment arrangement consisted of a set of thermistors calibrated to $\pm$ 0.2° C and estimated to 0.1 C and 10 plastic basins measuring 1.5' x 1.5' x 1' which were placed on a raised platform consisting of 2 x 4's and plywood. The experiments were carried out in the absence of any shade or possible longwave radiation other than atmospherc, fig. 1.

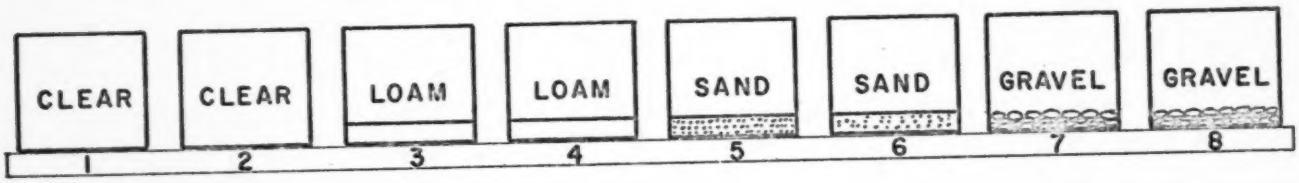


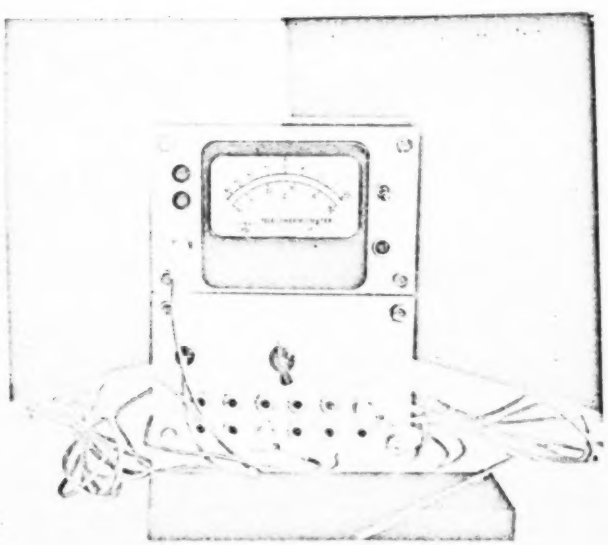
FIG. 1
BASINS FOR BOTTOM MATERIAL AND TURBIDITY EFFECTS ON TEMPERATURE RISE OF WATER

At the beginning of each experiment the basins were filled with approximately 70 liters of water. Four conditions, each employing two basins, were set up. Cne basin on each end insured uniform exposure to solar radiation for each basin.

Stream Turbidity

To study the stream turbidity effects suspension of bentonite clay in strengths of 1, 2, and 4 mg/l were prepared in the basins. Two basins with clear water were used as controls. Other means of producing turbidity were tried such as dyes, clay suspensions, distillation of turbid waters and bentonite clay suspensions. All these substances produced a spectrophotometric wave length absorption peak at 625 but the last one with bentonite is by far the easiest to achieve. The bentonite remained in suspension with only very limited settling being observed.

Thermistors were placed in the bottom of each basin and near the surface on the shady side. The thermistor leads then led to a junction box then to a Yellow Springs telethermometer, fig. 2.



Telethermometer Junction Box and Thermistors

Fig. 2

Thus rapid measurements could be made from one position during a brief time interval. It is thus assumed that simultaneous observation of conditions in each basin were made. Hourly temperature readings were noted for all thermistors from 8 am to 6 pm.

Stream Bottom Materials

The same procedure was used for studying the influence of different bottom materials with two basins each of clear plastic over plywood, two each of loam, two each of sand and two each of gravel. The loam was placed in the basin then covered with plastic and filled with water. After filling, the plastic was slowly withdrawn to prevent trubidity in the water. The sand and gravel were both washed before placement.

DISCUSSION OF THE RESULTS

Stream Turbidity

The results obtained in the first experiment are shown graphically in figures 3 through 6.

Clear water has a temperature gradient of 2^{o} for a large part of the day and almost the same temperature from top to bottom during the latter part of the afternoon indicating that radiant energy peretrates deeply into clear water and that in the afternoon thermal currents destroy the gradient. As fig's 4, 5, and 6 indicate there is a gradual increase in the temperature gradient as the turbidity increases, which means that the radiant energy is diffused by the particulate matter into the upper layers of water and that thermal currents are of very little consequence, the upper layers being much lighter so that there is very little mixing.

However the averaging of the surface and bottom temperatures for each period of the day produces a temperature curve with time which is essentially the same for each water mass regardless of the clarity or turbidity. It is therefore evident that although the heat energy distribution in turbid waters varies from that of clearer waters, nevertheless the total energy absorbed remains the same.

Stream Bottom Materials

In figures 7 through 10 the effects of different bottom materials are illustrated.

These curves indicate first of all that bottom materials do permit a certain amount of bed storage over that possible for the

plastic bottom. Since the plastic is a substance which transmits energy rather than absorbing it, it is concluded that bottom materials close to the surface of the water do contribute to additional energy being absorbed by the overlying water mass probably by absorption into these layers and then returning this energy by conduction and reradiation.

Secondly the graphs indicate very little difference between loam, sand, and gravel; all having about the same temperature curves.

The same change of temperature gradient may be noted in each case being more pronounced in the clear bottom basins. It is also noted that the gradients before and after the gradient inversion remain at 0.5 - 1.5^{o} C.

There appears to be little in the way of a gradient in the late afternoon all the water being mixed by density currents introduced by heating of the water mass.

CONCLUSIONS

Stream Turbidity

The first part of the experiments realted to turbidity indicates energy storage in surface layers with increasing turbidity. In a stream this is of little consequence, the stream being generally considered as totally and continously mixed. In reservoirs this phenomena is of considerable importance as here sharp diurnal temperature gradients influence evaporation and back radiation very directly, an increase of surface temperature will also increase the evaporation and back radiation.rates, such diurnal increases may aid the reservoir cooling by increasing the energy loss mechanism of evaporation and back radiation. It may be profitable to study such application in future research work.

Energy concentration due to turbidity in the upper reservoir layers will, therefore, materially assist in reducing the energy absorption of the reservoir as a unit. The upper layers will function as an insulation blanket for lower reservoir strata when such waters are needed for stream temperature control. The overall water quality, as it relates to the biota in the reservoir and stream, may be adversely affected by such turbidities but at least certain benefits may be realized. The diurnal inversion of the temperature gradient near the surface is of similar interest, and very little of these aspects of surface temperature variation is known quantitatively. It may be assumed that in reservoirs the above described gradients may not be as steep, but their existence must be presumed until further work indicates otherwise.

Stream Bottom Materials

The results of part two of the study related to bottom materials has shown that the bottom material quality itself whether loam, sand, of gravel is of little effect with respect to other materials. There is however a noticable effect as the increase of the total energy stored in the overlying water mass is considerably greater than for clear water over a transparent bottom and may be noted in several degrees higher temperature of the water mass. Variations of this effect with increasing depth have not been investigated and provide a basis for future work.

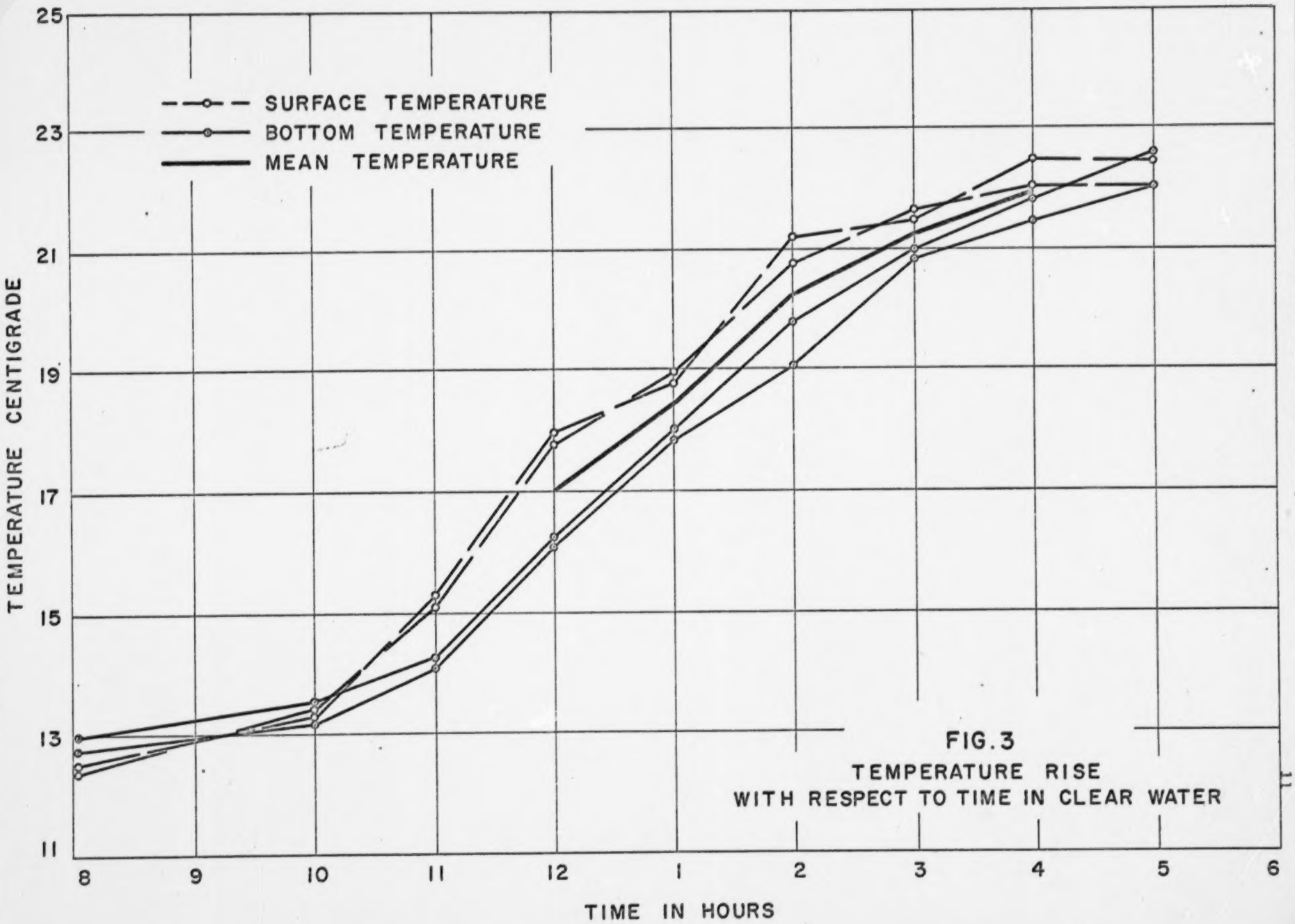


FIG. 3

TEMPERATURE RISE
WITH RESPECT TO TIME IN CLEAR WATER

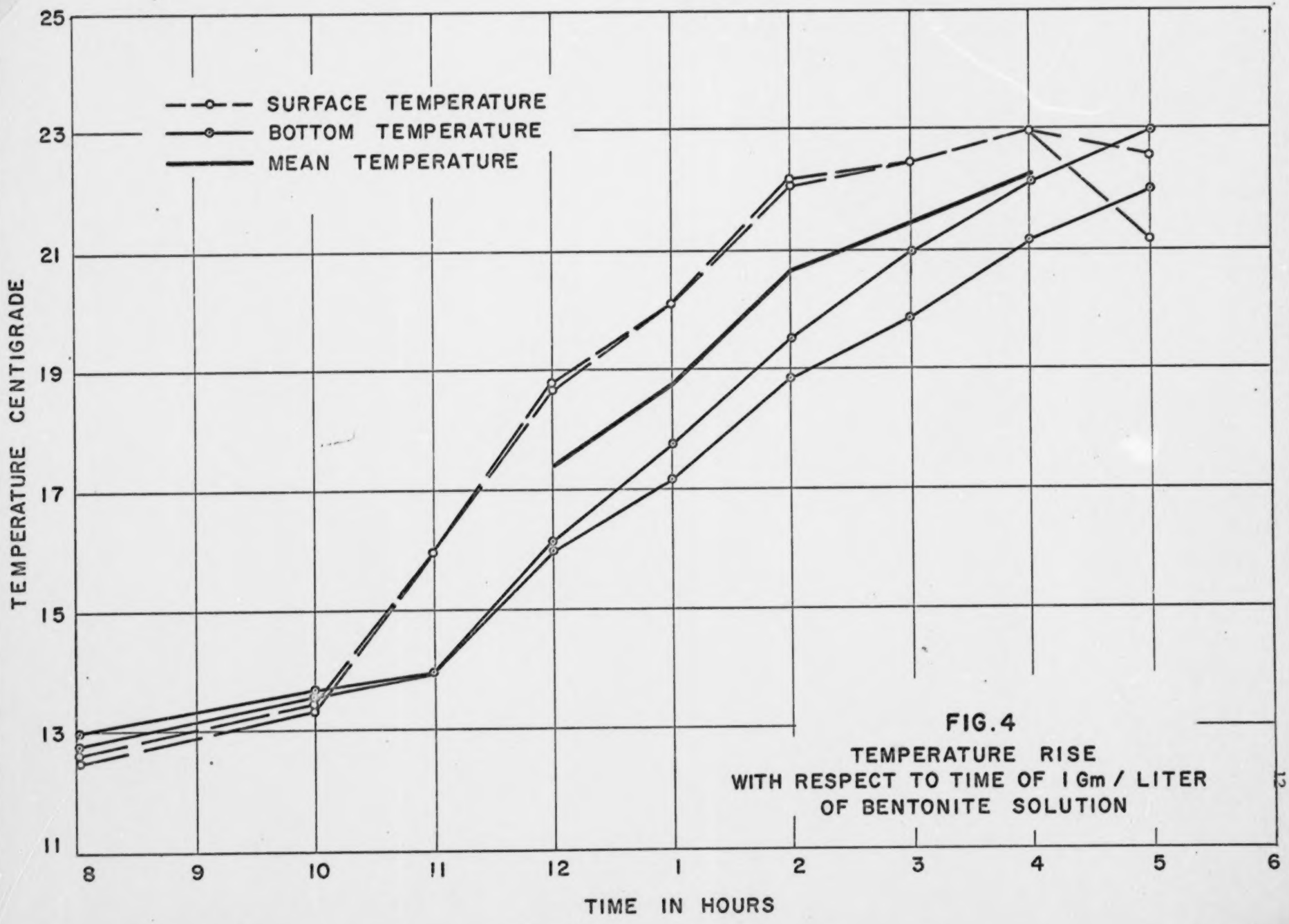


FIG. 4

TEMPERATURE RISE
WITH RESPECT TO TIME OF 1 Gm / LITER
OF BENTONITE SOLUTION

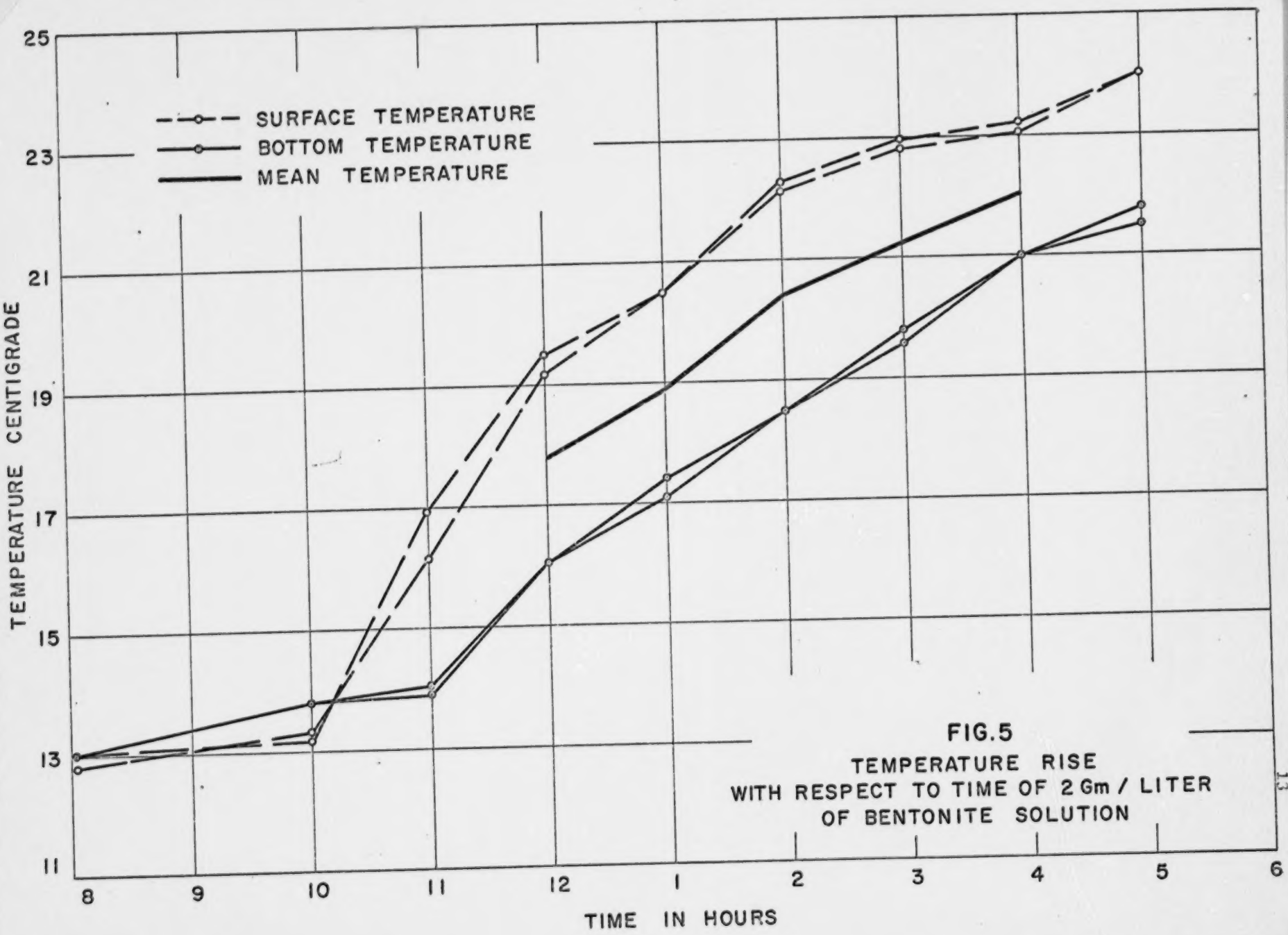


FIG.5

TEMPERATURE RISE
WITH RESPECT TO TIME OF 2 Gm / LITER
OF BENTONITE SOLUTION

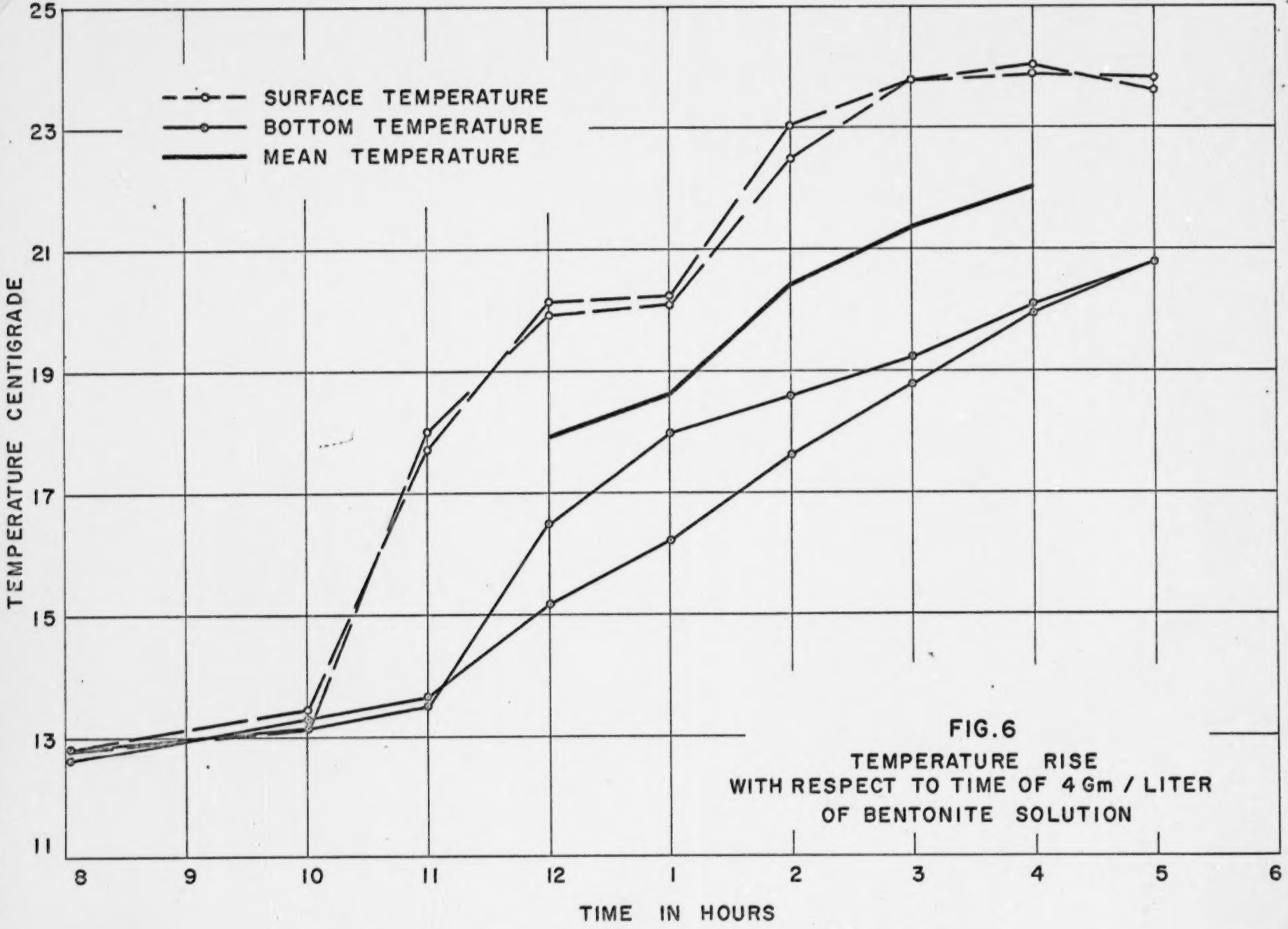


FIG.6

TEMPERATURE RISE
WITH RESPECT TO TIME OF 4 Gm / LITER
OF BENTONITE SOLUTION

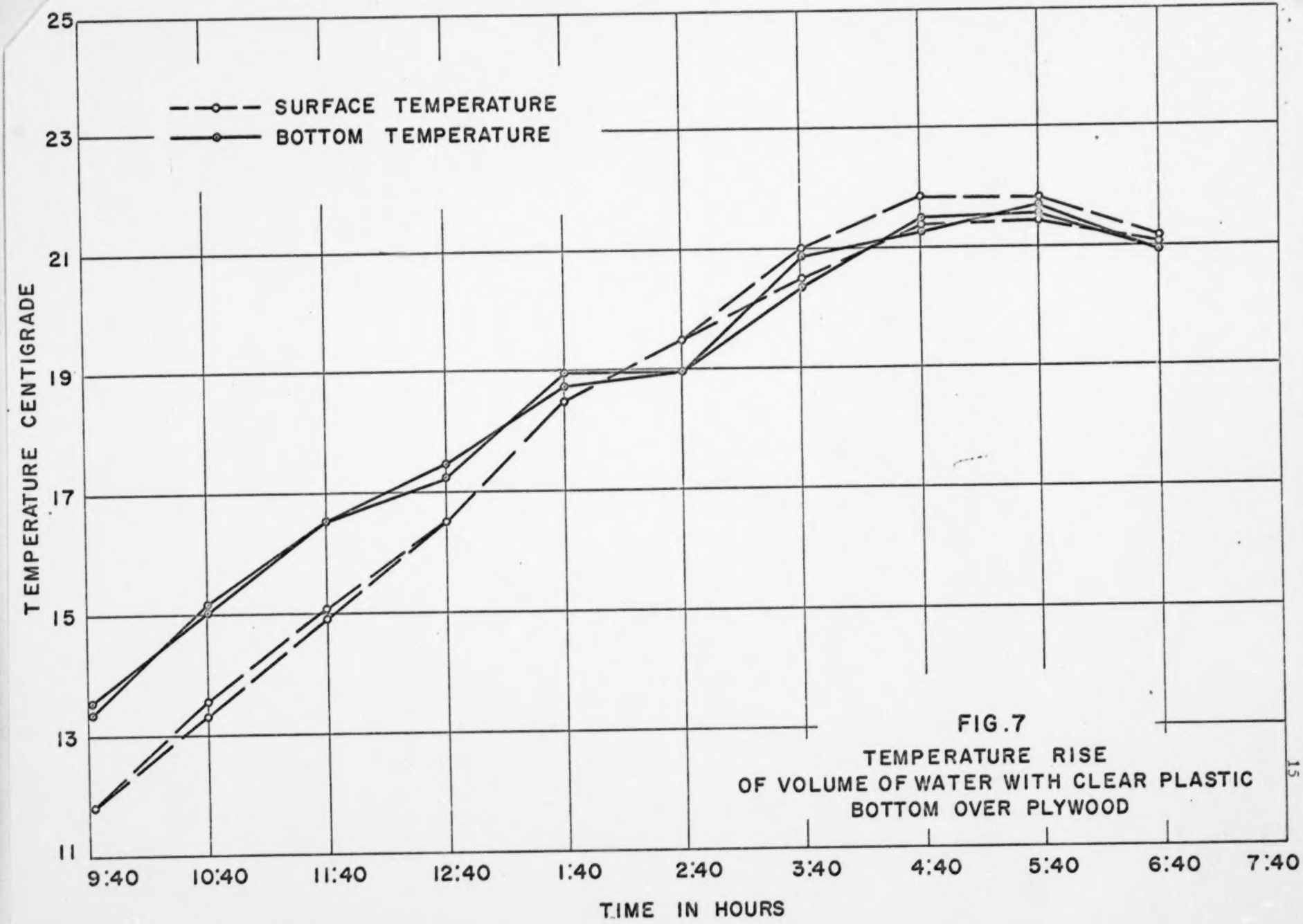


FIG.7

TEMPERATURE RISE
OF VOLUME OF WATER WITH CLEAR PLASTIC
BOTTOM OVER PLYWOOD

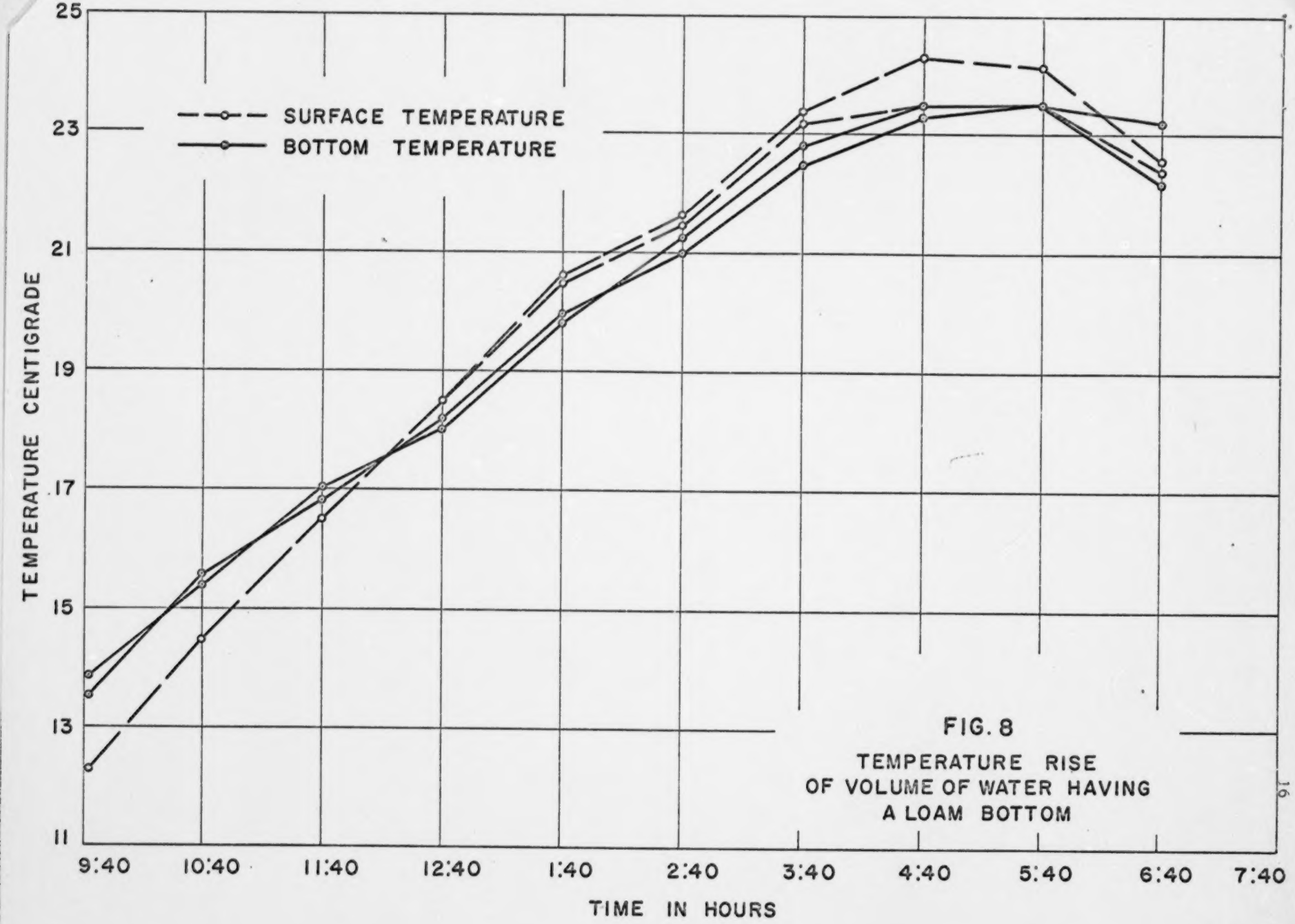


FIG. 8

TEMPERATURE RISE
OF VOLUME OF WATER HAVING
A LOAM BOTTOM

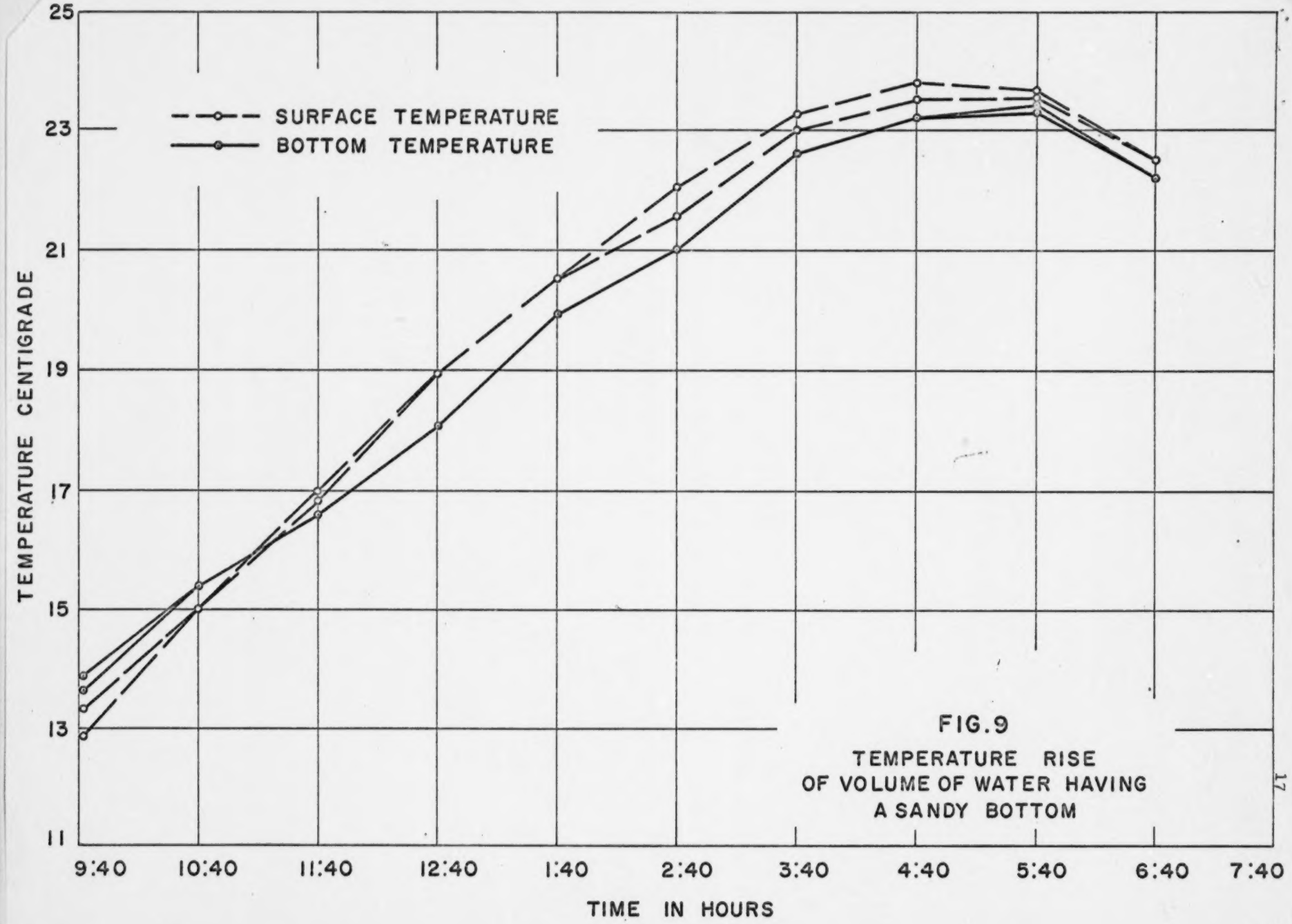


FIG.9

TEMPERATURE RISE
OF VOLUME OF WATER HAVING
A SANDY BOTTOM

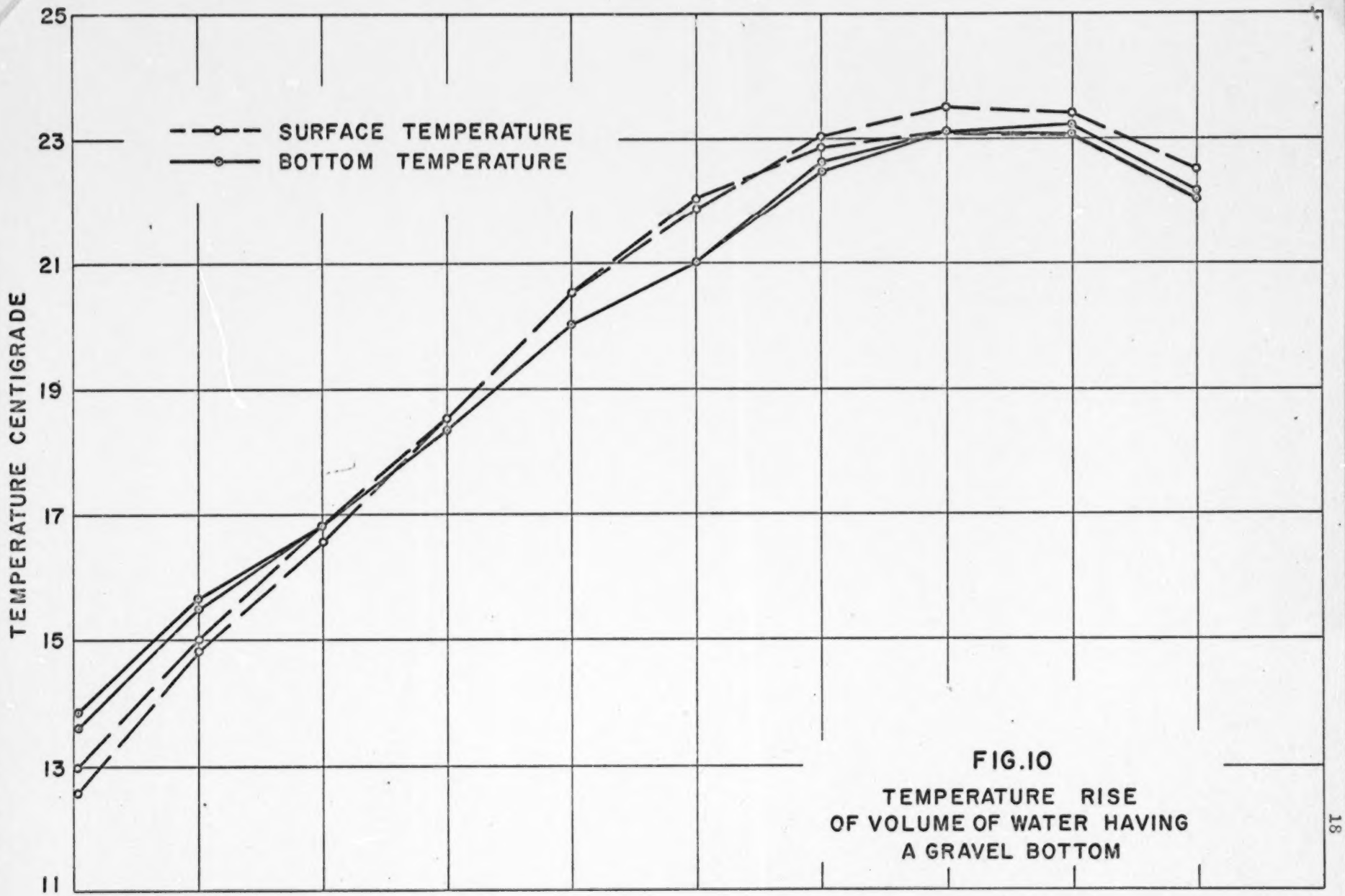


FIG.10

TEMPERATURE RISE
OF VOLUME OF WATER HAVING
A GRAVEL BOTTOM